TopNET Evolution

Session: Test and Verification

Short Paper

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Abstract

The Virtual Spacecraft Integration (a.k.a. “TopNET”) is achieved through the use of a network such as the Internet. To determine the benefits and limitations of virtual spacecraft integration, ESA conducted a pilot study involving spacecraft and equipment manufacturers in different countries across Europe. They conducted experiments using the SpaceWire Internet Tunnel device to remotely integrate components and reported back on their findings. Their results were very positive. Despite the identified benefits, there are potentially some limitations of virtual spacecraft integration. In the paper, the outcome of the pilot study will be shortly summarized, and a strategy to enhance “synchronous” communication will be presented. Moreover, a further objective is to extend the TopNET concept, having in mind the CCSDS SOIS architecture.

1 Introduction

The concept of virtual spacecraft integration has been described in previous papers by ESA/University of Dundee [2]. It provides a means by which integration and testing of spacecraft components can be performed without the need to bring each of the components to one physical location. The SpaceWire standard [1] aims to improve reusability, promote compatibility and reduce system integration costs. Virtual spacecraft integration has the potential to reduce system integration costs still further, by reducing travel and by identifying problems at an earlier stage of spacecraft development than is currently the case.

Virtual integration is achieved through the use of a network such as the Internet. A section of the spacecraft’s onboard bus is replaced with a virtual connection over the network, allowing components to communicate with one another, despite potentially being great distances apart.

2 The SpaceWire Internet Tunnel

The SpaceWire Internet Tunnel is a tool for performing virtual spacecraft integration in a SpaceWire network and it has been originally developed by the University of Dundee under ESA contract. An example SpaceWire network which could benefit from virtual spacecraft integration is shown in Figure 1. This network contains two separate sub-systems, which may be developed by different companies, possibly in different countries. This is quite common in European missions, for example.

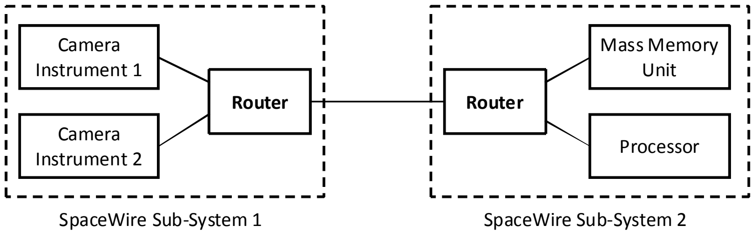

Figure 1: Example SpaceWire network containing two distinct sub-systems

A SpaceWire Internet Tunnel replaces a SpaceWire link in an onboard network, and consists of both software and hardware components. A SpaceWire cable representing one end of the link to be replaced by the SpaceWire Internet Tunnel is connected to a SpaceWire IP-Tunnel device. This device is then connected to a PC by a USB cable. Software running on the PC manages the Tunnel and allows traffic crossing the Tunnel to be monitored and recorded. A similar set-up is used at the other end of the link being replaced, and the software running on the two PCs tunnels traffic received on the SpaceWire links over a network to the other end. This arrangement is shown in Figure 2, where the two sub-systems from the example network in Figure 1 have been connected virtually using a SpaceWire Internet Tunnel. These two sub-systems may be in the same lab, or may be in different continents.

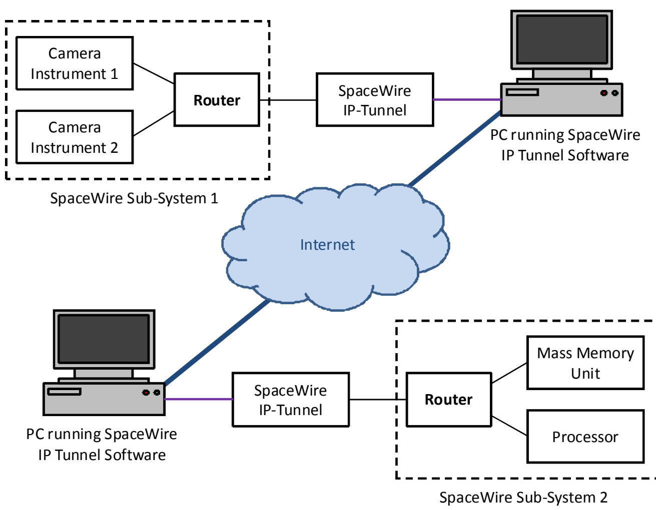

Figure 2: Example SpaceWire network containing two sub-systems integrated virtually

As well as exchanging data packets, the Tunnel also ensures that the link state is reflected at each end of the Tunnel. This means that if a link is disconnected at one end of the Tunnel, the link at the other end will also be disconnected. Other than the increased latency and reduced bandwidth, the Tunnel is almost transparent.

3 THE TOPNET PILOT STUDY: BENEFITS AND LIMITATIONS

An ESA funded pilot study, the "TopNet Pilot Study", was implemented to investigate the benefits and limitations of virtual spacecraft integration when in use within a real project environment. The study involved three consortia, each consisting of partners spread across Europe. Each consortium proposed experiments where SpaceWire devices situated in each of the consortium's partners would be virtually integrated.

On completing their experiments, each consortium presented their findings. They also compiled a report containing their results and conclusions. The general consensus of those involved in the pilot study is that although there is still the possibility to make improvements, virtual spacecraft integration and the SpaceWire Internet Tunnel is a very useful tool for performing integration testing. Virtual spacecraft integration has the potential to reduce costs and time in spacecraft development, while also improving the completed product. By allowing integration testing of spacecraft components to be performed at an earlier stage, problems in interfaces and at the application level, for example, can be identified and corrected earlier, which reduces the time and money required to address such issues. Travel can also be reduced through use of virtual spacecraft integration as components can be integrated without bringing them to a single physical location. This has an environmental benefit in addition to a financial one.

Cooperation between organisations, or between sites within one organisation, can also be improved through use of virtual spacecraft integration. Engineers working on different subsystems, who may not normally have contact with one another until the integration phase late in the development cycle, may instead communicate at an earlier stage in the development cycle. Virtual spacecraft integration also provides much more flexibility than traditional integration procedures. The time at which integration testing is performed is much more flexible, as devices do not all need to be in the same place at a specific date and time. It is also easy to replace components with simulators when performing virtual integration testing, while test and analysis equipment can also be integrated virtually.

Despite these benefits there are potentially some limitations of virtual spacecraft integration. Use of a network connection such as the Internet introduces limits in bandwidth and latency. Neither are guaranteed in Internet communication, and both bandwidth and latency can vary greatly during a connection's lifetime. This limitation can affect cases when synchronous communication is required during the integration of two different modules.

Firewall restrictions can pose a problem to virtual spacecraft integration. In Internet communications there must be a server present. Such servers normally require special firewall permissions to be granted by a network administrator, and these permissions may not always be given to PCs running in a lab. Some organisations only allow certain traffic, such as web and FTP, to cross their firewall. The addition of a SpaceWire Internet Tunnel Server can address the firewall issue, where PCs cannot act as a server behind a company's firewall.

4 ENHANCING SYNCHRONOUS COMMUNICATION

Starting from the valuable feedback received by the pilot study, it seems necessary to improve the TopNET concept, in order to overcome the above-mentioned limitations. In particular, the latency can affect cases when synchronous, real time communication is required during the integration of two different modules.

For the Internet tunnelling communication, regular TCP/IP is used. It is well-known that TCP/IP implements a “best-effort” paradigm without guaranteeing latency. The reason for this is that queuing delays sum up at each router. TCP/IP is a “best effort” protocol and tries to fill the routers queues. Possible solutions in order to have a guaranteed latency are to use a customised communication protocol**:**

- TCP Westwood+ [3] is available in Linux kernel and it is a sender-side only modification of the TCP protocol stack that optimizes the performance of TCP. The use of TCP Westwood+ can provide benefits in terms of latency, since it is known to provide less queuing. In case of a particular scenario, i.e. when the bandwidth of the tunnel is known, as it is in corporate intranet, TCP Westwood+ can be further optimised to improve the performances.

- Design rate-based transport protocol at application level executed over the UDP, as it is done for applications that are time-sensitive, such as VoIP or Video Conferencing [4].

If the suggested modification for the Internet Tunnelling communication will bring the expected benefits and a guaranteed latency is obtained, new opportunities will be created for the Virtual Satellite Integration, where real-time communication will be possible. If the latency, other than been guaranteed, is also low enough, the TopNET concept could be extended to consider additional Data Link Layers besides SpaceWire, in order to cover the full CCSDS SOIS architecture [www.ccsds.org].

5 TopNET Evolution: Conclusions

In this paper, the outcome of the Pilot Study has been shortly summarized, and a strategy to enhance “synchronous” communication has been presented. The long term objective is to extend the TopNET concept, having in mind the CCSDS SOIS architecture. This means the introduction of additional Data Link Layers besides SpaceWire and the use of Quality of Service metrics. Future activities planned by ESA will pave the way to reach these objectives.

6 References

1. European Cooperation for Space Standardization, “SpaceWire, Links, Nodes, Routers and Networks”, Standard ECSS-E-50-12A, Issue 1, European Cooperation for Space Data Standardization, February 2003.

2. S. Mills, S. Parkes, R. Vitulli, “The SpaceWire Internet Tunnel And The Advantages it Provides for Spacecraft Integration”, International SpaceWire Conference 2008, Nara, Japan, November 2008.

3. A. Dell'Aera, L. A. Grieco and S. Mascolo, “Linux 2.4 Implementation of Westwood+ TCP with rate-halving: A Performance Evaluation over the Internet”, IEEE International conference on Communication (ICC 2004), Paris, June 2004.

4. L.A. Grieco, S. Mascolo, “Adaptive Rate Control for Streaming Flows over the Internet”, ACM Multimedia Systems Journal, Regular paper, Volume 9, Issue 6, pp. 517 -532, Jun. 2004.